Anatomy of the Upper Extremity

Introduction

The extremities consist of bones, muscles, arteries, and nerves. They are separated into compartments. Muscles cross joints to move bones relative to one another. When you have achieved a mastery of the structure and function of the extremities, everything fits together. Building up that knowledge is hard because any one feature requires knowledge of the other, but you must acquire the knowledge linearly. So we start MSK with three lessons dedicated to the upper extremity. We spend this first lesson on fundamentals: bones, muscles, arteries. The second lesson uses these fundamentals to explore in detail the joints of the upper extremity and to explore pathologies of those joints. The third lesson discusses the brachial plexus, sensory innervation, motor innervation, and pathologies of those innervations. Finishing the first lesson will be dissatisfying. But after finishing all three, and then putting them together, you will have mastered the material. There is no perfect way to present it—there is vastly too much information for one lesson, so we divide it between three. We assume you have some fundamental anatomy background.

In this lesson, we walk you through each section, building on what you learned in the section before. We start with the bones. We name them and make mention of the muscles and joints they will participate in. We then engage the joints without the details of the muscles that control them. We then add on the muscles that move those joints. Finally, we conclude with the arteries that feed those muscles and bones. Problems with joints are discussed in MSK #2: *Joints of the Upper Extremity*, and problems with sensory and motor are covered in MSK #3: *Nerves of the Upper Extremity*.

Bones of the Upper Extremity

There are three general regions of bones of the upper extremity—the shoulder, the arm, and the hand. Bones are what muscles connect to. Refer to Figure 1.1 as you read. The anatomy and physiology of bones in general is covered in the Endocrine module.

Bones of the shoulder. Three bones articulate to form the shoulder—the clavicle, scapula, and humerus. The humerus is the bone of the arm. The **scapula** is a large flat bone from which the rotator cuff muscles originate. The scapula is a large flat bone that rests just behind the rib cage. On the posterior of the scapula is the scapular **spine**, a ridge that protrudes posteriorly. At the end of the spine is the acromion. The rest of the scapula continues forward anteriorly, where it becomes the coracoid process. The scapula consists of the long flat portion where muscles connect, the spine that separates the flat bone into upper and lower portions, the lateral termination of the spine (the **acromion**), and the lateral termination of the flat bone (the **coracoid process**) The **clavicle** is the collarbone, attached to the axial skeleton at the sternum and free-floating at the shoulder. Each of these structures—coracoid, acromion, and clavicle—is connected to the others by ligaments. The rotator cuff muscles will originate on the scapula and connect to the humerus. The larger muscle of shoulder movement will originate on the axial skeleton—clavicle, pelvis, spine—and go around or over these bones to insert on the humerus.

Bones of the arm. The **humerus** is the bone of the upper arm. It has condyles and fossae, the details of which will be discussed as they become relevant to the shoulder and elbow. The forearm is made of the **radius** and **ulna**. The radius, in anatomical neutral position (arms straight at the sides, thumbs pointing away from the body, palms forward), is **lateral** to the ulna, making the ulna **medial**. When you take a patient's radial pulse, you compress the artery against the bone on the thumb side of the forearm. The radius is on the thumb side, the ulna on the pinky side. Each of these bones is a **long bone**, with a diaphysis (shaft) between two ends, each end with a metaphysis (transition from shaft to end), and an epiphysis (the end of the long bone). The joint formed between the radius-and-ulna and the humerus is the elbow. The join formed between the bones of the hand and the radius-and-ulna is the wrist.

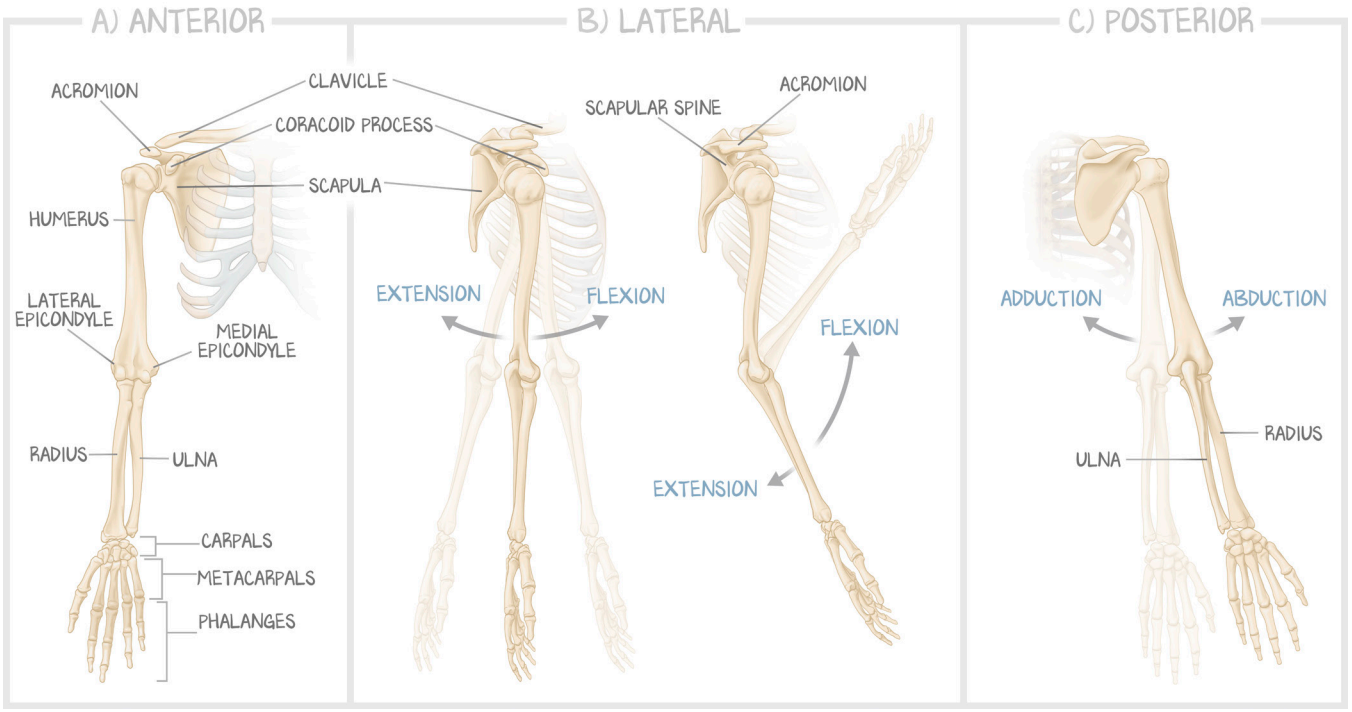

Figure 1.1: Bones of the Shoulder and Arm
The bones of the shoulder, arm, and hands as seen from (a) the front, (b) the side, (c) the back. The lateral panel also demonstrates flexion and extension at the shoulder and elbow. The posterior demonstrates abduction and adduction.

Bones of the hand. There are many bones in the hand. There are eight carpal bones at the base of the hand and five metacarpals that make up the rest of the palm. Each finger has three phalanges: a proximal, middle, and distal, except for the thumb, which has only proximal and distal phalanges. That's 27 bones in each hand. Thankfully, we can reduce these bones to patterns—metacarpals, phalanges, and carpal bones—rather than learning about all 27 individually.

The **carpal bones** are at the base of the palm. There are 8 of them, and you should be able to identify all 8 on an X-ray. Figure 1.2 takes you through an illustration and an X-ray, with a mnemonic. The **thumb** is known as **digit 1**, and the region of skin and muscle around the thumb bone on the palmar surface of the hand is referred to as the **thenar eminence**. The pinky is known as **digit 5**, and the region of skin and muscle around the pinky bone on the palmar surface of the hand is referred to as the **hypothenar eminence**. In the supine position, palms facing forward, the thumbs, and therefore the thenar eminences, are lateral, while the pinkies, and therefore the hypothenar eminences, are medial.

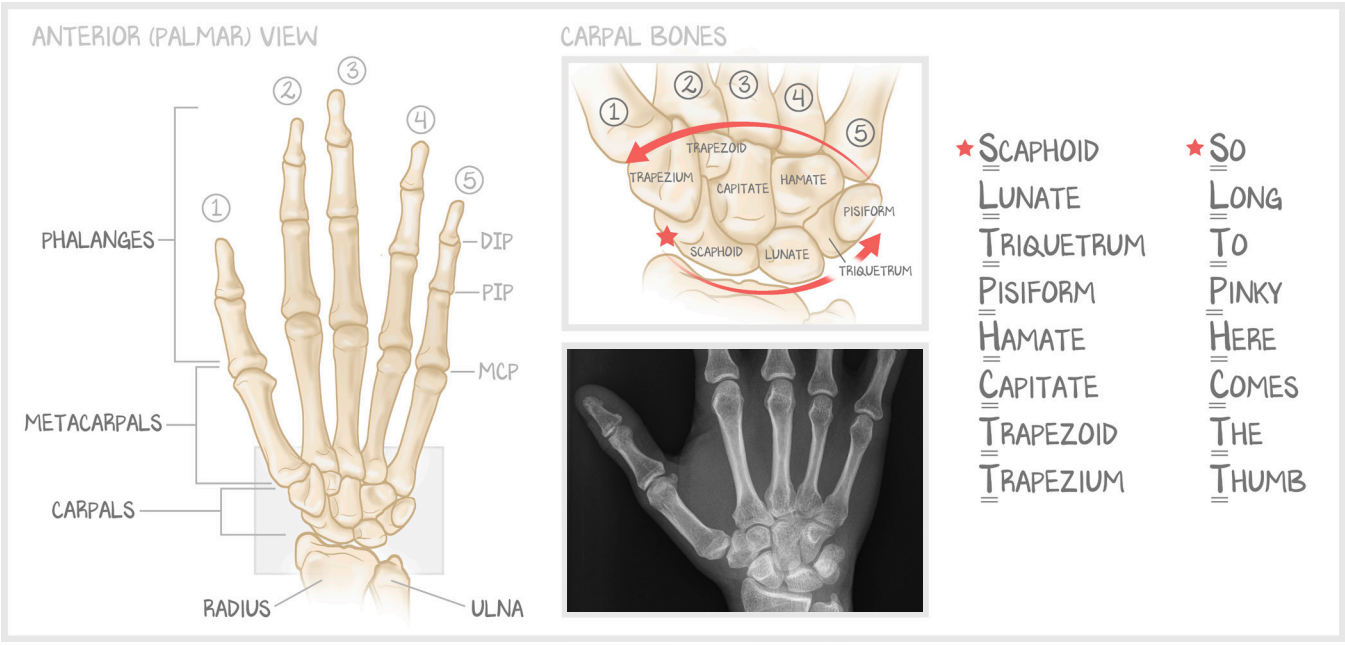

Figure 1.2: Bones of the Hand
An anterior view shows the hands of the fingers—Phalanges and metacarpals. The zoombox shows the carpal bones in detail as they correspond to the radiograph below it. Use the mnemonic, "So Long To Pinky, Here Comes The Thumb." Find the scaphoid first. It is in the row of bones that is proximal and also the most lateral of the proximal bones (thumb side, radius side). Start the organizer at the scaphoid: **S**caphoid, **L**unate, **T**riquetrum, **P**isiform (So Long To Pinky) moving from the thumb side along the radius toward the pinky side at the end of the ulna. Then move "up" to the hamate, starting on the medial side (the pinky side) and move back toward the thumb, laterally. **H**amate, **C**apitate, **T**rapezoid, **T**rapezium (Here Comes The Thumb).

Metacarpals (the bones at the base of the fingers) meet the proximal phalanges at the metacarpophalangeal joints (MCPs). Each proximal phalanx meets its middle phalanx at the proximal interphalangeal joint (PIP, "*pee eye pee*," pronounce each letter). And the middle phalanges meet the distals at the distal interphalangeal joints (DIPs, "*dee eye pees*," pronounce each letter). The thumb has only one interphalangeal joint. MCPs, DIPs, and PIPs become relevant in autoimmune disease as well as neurologic dysfunction of muscles of the hands, and mastering this content is important before we get there. Work through the joints of your own hand. Turn your right hand to be perpendicular to your face, pointing your fingers straight up. You should look like you are about to do a karate chop. Bend your index finger. Starting at your nail, work backwards. The first joint back from the nail is the DIP. The next the PIP. Now make a fist. Your thumb ends just under the PIP. The knuckles at the top of the fist, are the MCPs.

Joints

Building on the bones, we now explore the joints and how they work. The shoulder is between the scapula and humerus, the elbow is between the humerus and the forearm bones, and the wrist is between the forearm bones and the carpal bones. For this discussion, the muscles don't matter. We're not discussing origin and insertion, just exploring how the bones could move if there were muscles there. In the following section we'll add the muscles and what they do.

The **shoulder** is a **ball-and-socket** joint. You should think of the humerus (the ball) sliding along the glenoid cavity of the scapula (the socket), surrounded by a joint capsule. The rotator cuff muscles stabilize the humeral head within the glenoid (they keep it steady against the glenoid cavity) while the non-rotator-cuff muscles pull it in the different directions. The rotator cuff muscles run through the shoulder joint, within the glenohumeral fossa. The shoulder can abduct, adduct, internally rotate,

externally rotate, flex, and extend. The muscles that do that are the large muscles—pectorals, deltoid, latissimus, serratus—that pass over or around the shoulder joint. The space between bones contains a fluid-filled sac, called the bursa. We spend a lot of time with this joint in the next lesson, so we move quickly through it here.

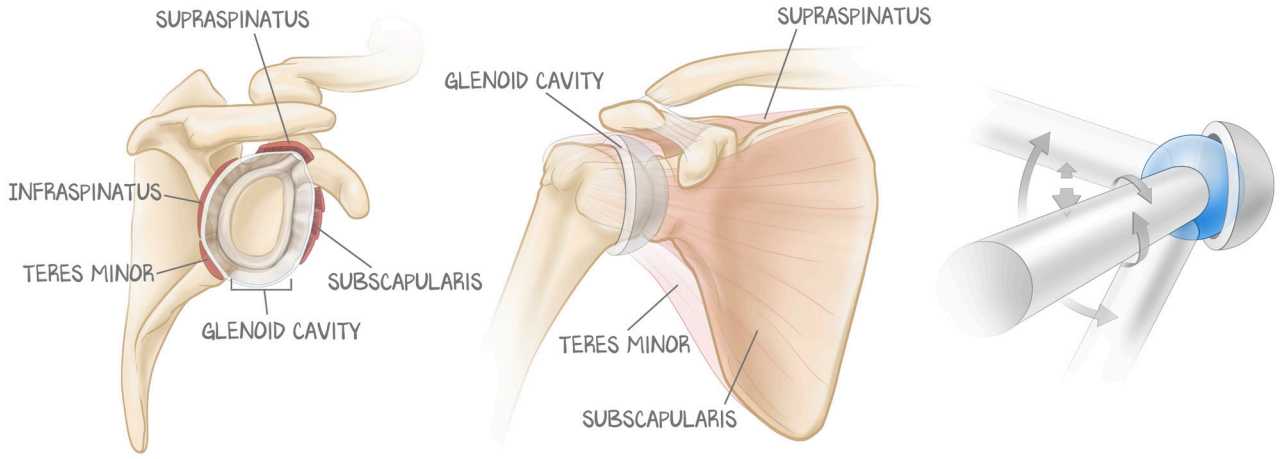

Figure 1.3: The Shoulder Joint
The shoulder joint is a ball and socket joint, the glenoid cavity serving as the socket for the head of the humerus. With just a hint of the SITS muscles represented, the focus should be on the joint, but their relative anatomy is previewed as well.

The **elbow** is made by the connection between the humerus and the radius/ulna. This is a simple joint—it either flexes (the arm bends) or extends (the arm goes straight). There are two bones in the forearm, so those bones can be turned over one another, allowing for pronation and supination of the hand, but the elbow joint itself only bends. The end of the humerus has two projections called epicondyles, one medial, and one lateral. Between the epicondyles is a divot into which the **olecranon of the ulna** moves into when the arm straightens. The radius has only a **radial head** that abuts the **lateral epicondyle** of the humerus. When the arm flexes, the radial head moves away from the lateral condyle and the olecranon moves out of the divot. When the arm straightens, the olecranon moves into the divot and the radius comes up against the lateral epicondyle. The **ulnar nerve** runs over the back of the humerus, through a groove, and then alongside the ulnar bone. This is your "funny bone," and the sensation of pain and paresthesia that happens when it's hit is due to an injury of the ulnar nerve. There is also a **bursa**, which sits on top of the olecranon; the bursa can become inflamed.

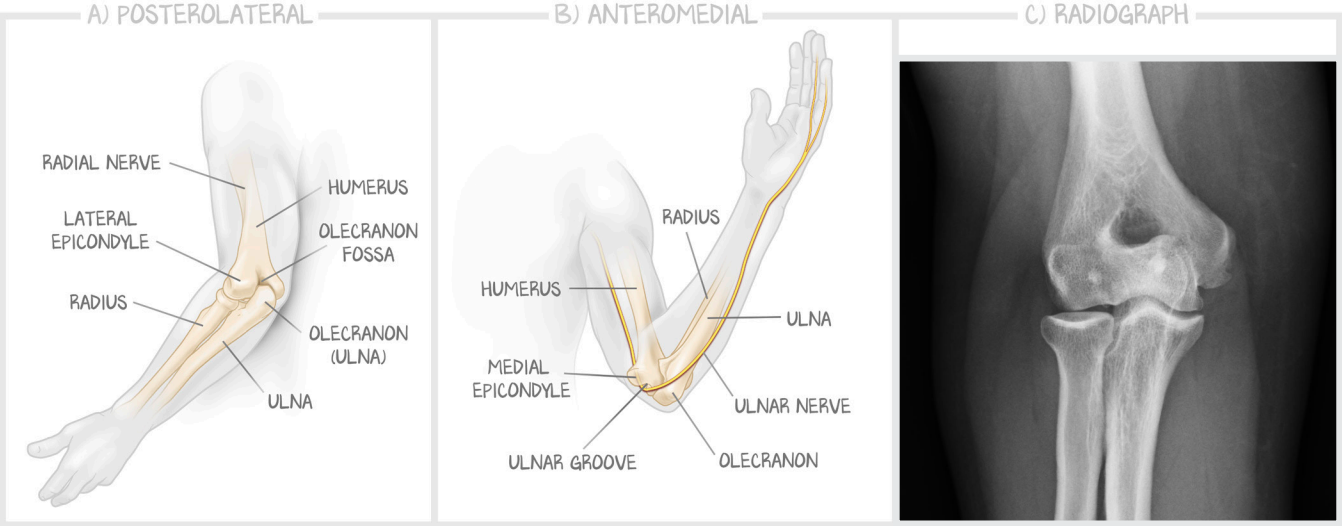

Figure 1.4: The Elbow
(a) A posteromedial view shows the ulnar nerve in the ulnar groove of the medial condyle of the humerus as well as the medial view of the olecranon. (b) A posterolateral view depicts the radial head interacting with the lateral epicondyle. (c) The plain film of an X-ray identifies the bones of the joint.

The **wrist** is where the radius/ulna touches the carpal bones of the hand. The nerves, arteries, and tendons originating from the forearm insert into the hand, through the wrist. When those forearm muscles contract, the hand moves. The hand can move side to side (toward the radius or toward the ulna) and up and down (flex, extend), and can be flipped over (supinate, pronate). Those movements are all controlled by muscles of the forearm, their tendons passing through the wrist to the hand. The pathologies of the wrist, therefore, will not be about the joint itself, but about the things passing through it. (The details of the carpal tunnel and the Guyon canal are discussed in the next lesson.)

Muscles of the Upper Extremity

Starting from the neck and moving down the arm, the first joint is the shoulder. We divide the shoulder muscles into rotator cuff muscles and not-rotator-cuff muscles.

The **rotator cuff** is group of small muscles that use the scapula as their origin. They are small, easily injured, and easily impinged, and all have similar-sounding names, making them great board fodder. There are also physical exam maneuvers with good likelihood ratios that can be used to assess them, making them clinically useful in assessing shoulder dysfunction. You should absolutely memorize this chart; the video will make it easier to remember, and subsequently deduce, the muscle-to-motion relationship. Rotator cuff vignettes are found on every licensing exam.

MUSCLE	ACTION	INNERVATION
Supraspinatus	Abduction 0°–15°	Suprascapular nerve
Infraspinatus	External rotation	Suprascapular nerve
Teres Major	External rotation	Axillary nerve
Subscapularis	Internal rotation	Subscapular nerves

Table 1.1: TSITS Muscles of the Rotator Cuff
Supraspinatus, infraspinatus, and teres major are on the posterior of the scapula (SIT); subscapularis (S) is the only one on the anterior. The subscapularis pulls the humerus toward the front of the scapula, internal rotation. The supraspinatus goes over the top, so is involved in initial abduction. The infraspinatus and teres major pull the humerus toward the back of the scapula, external rotation

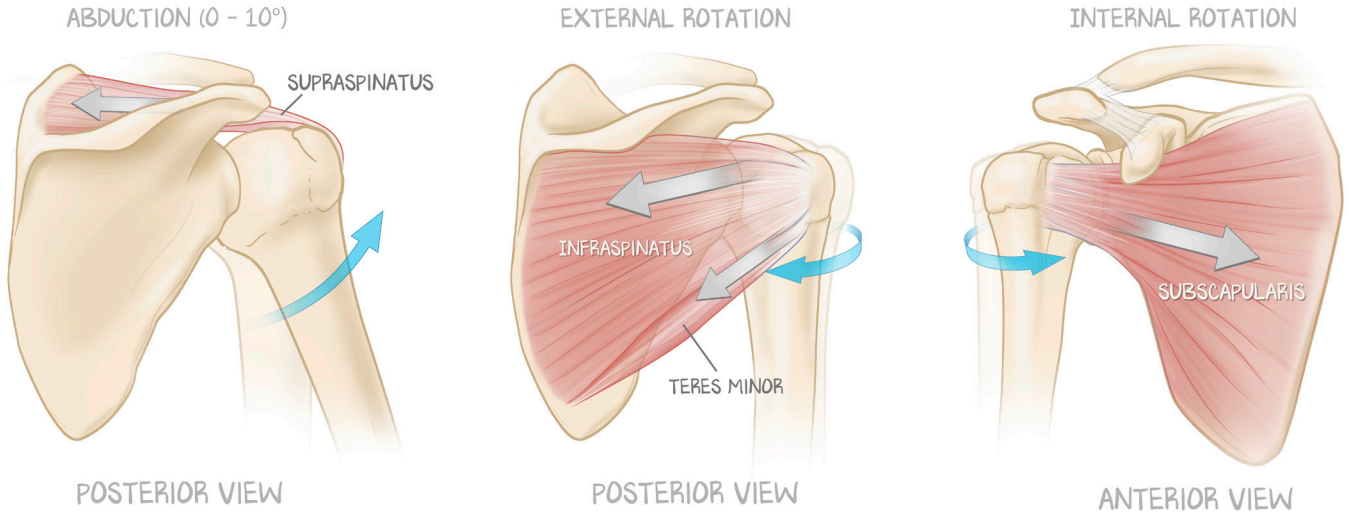

Figure 1.5: SITS Muscles of the Rotator Cuff
Anterior and posterior views of the scapula focus on the relative anatomy of the rotator cuff muscles. The origination on the scapula and insertion onto the humerus (anterior or posterior of each bone) suggest the motion the humerus will make with activation of that muscle. Supraspinatus abducts, infraspinatus and teres minor externally rotate, and the subscapularis internally rotates

The not-rotator-cuff muscles of the shoulder are the large muscles—deltoid, trapezius, serratus, pectorals, and latissimus dorsi. The muscles that move the humerus at the shoulder all have their origin on the axial skeleton and insert onto the humerus.

The **deltoid** is the muscle most commonly associated with the shoulder. The deltoid is responsible for abduction of the shoulder from 15°-100° and is innervated by the axillary nerve. The **trapezius** and **serratus** anterior also help with abduction, thought the deltoid is the primary muscle of shoulder abduction. The **latissimus dorsi** is the large muscle of the back, which serves to adduct, internally rotate, and extend the shoulder. The **pectoral muscles** adduct, internally rotate, and flex the shoulder.

MUSCLE	ACTION	INNERVATION
Deltoid	Abduct 15°–100°	Axillary nerve
Trapezius	Abduct > 90°	Accessory nerve, CN 11
Serratus anterior	Abduct > 100°	Long thoracic nerve
Latissimus dorsi	Adduct, extend, and internally rotate the shoulder	Thoracodorsal nerve
Pectoralis Major	Adduct, flex, and internally rotate the shoulder	Don't worry about this one

Table 1.2: Non-Rotator-Cuff Muscles
These are the large muscles of the shoulders, what they do, and their source of innervation. These large-mass muscles make the shoulder capable of such a range of motion with such stability.

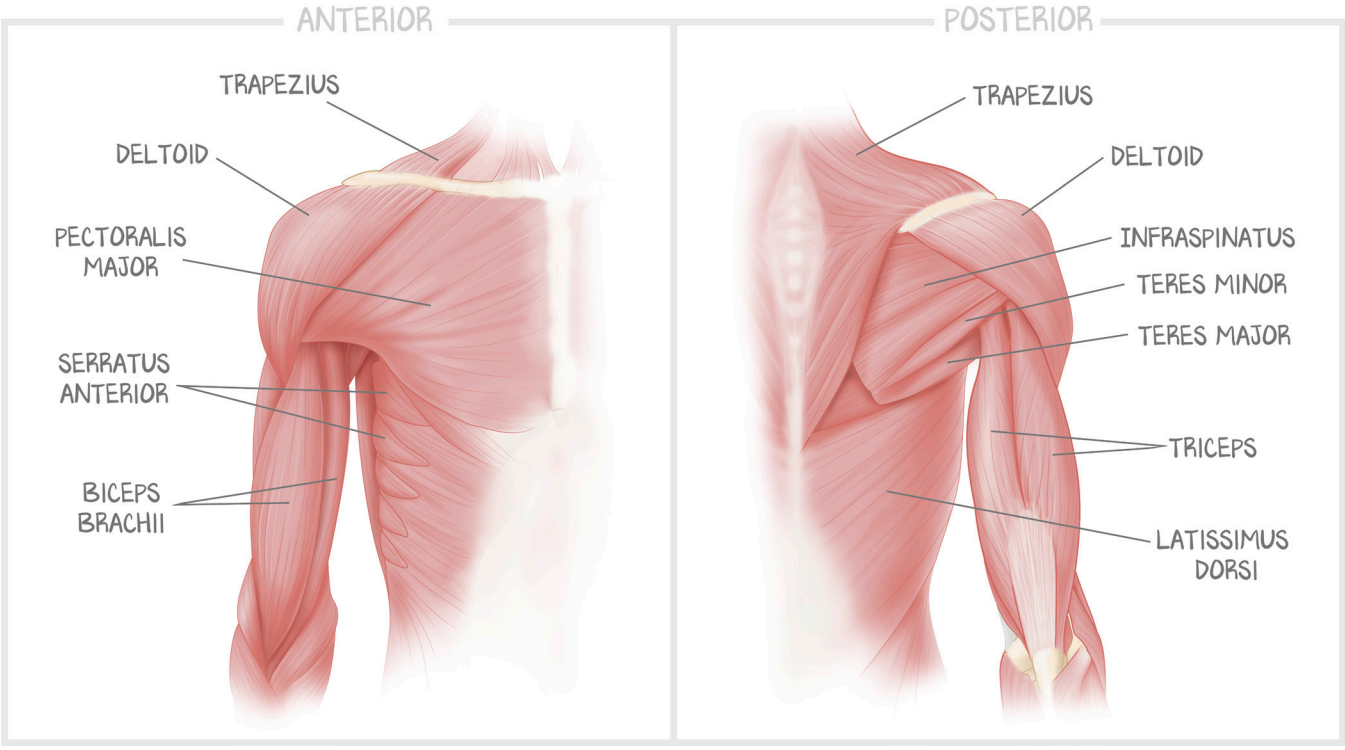

Figure 1.6: Large Muscles of the Shoulder and Arm
A composite of the anterior view and posterior view of the muscles. The latissimus, trapezius, deltoid, and pectoralis muscles all influence the movement of the humerus at the shoulder. These shoulder muscle functions are less easily deduced than those of the rotator cuff because they are so large and have many insertion points. In addition, the muscles of the arm (the biceps and triceps) originate on the clavicle and insert onto the forearm. The biceps and triceps origination on the clavicle make them "shoulder" muscles, too.

From the shoulder, we move down to the upper arm where there are two muscles—the biceps muscle and the triceps muscle. The **biceps** (so called because it has two heads, bi for two) are on the **anterior**, which serves to **flex the elbow** and **supinate the arm**. One head of the biceps originates from the humerus, the other from the coracoid process. The biceps muscle inserts into the bones of the forearm. The biceps is innervated by the musculocutaneous nerve. When contracted, it brings the forearm and humerus closer together. But because the biceps muscle originates also from the coracoid, and the

coracoid is glued to the clavicle by ligaments, the biceps muscle brings the forearm towards the clavicle, the humerus staying in place. The **triceps** (so called because it has three heads) on the **posterior**, which serves to **extend the elbow**. The triceps is innervated by the radial nerve.

You will see the orientation of "flexion anterior" and "extension posterior" repeated throughout all lessons of the extremities.

Absolutely do not learn the individual names of the muscles of the forearm. The muscles of the forearm are actually the **extrinsic muscles of the hands**. Following the precedent of biceps-anterior-flexion and triceps-posterior-extension, we simplify the muscles of the forearm by packaging them into compartments. The compartments do a motor action and receive a motor nerve input.

The **anterior compartment** is the **flexor compartment**, which is innervated by the **median** and **ulnar** nerves and is responsible for the **extrinsic** flexor muscles of the wrist and fingers. The **posterior compartment** is the **extensor compartment**, which is innervated by the **radial nerve** and is responsible for the **extrinsic** extensor muscles of the wrist and fingers. These muscles originate in the forearm and their **tendons only** enter the hand through the wrist. As we will see in the nerve lesson, the motor innervation mirrors the sensory dermatomal innervation (radius posterior, ulna anterior medial, median anterior lateral). More on that in MSK #3: *Nerves of the Upper Extremity*.

MUSCLES	ACTION	INNERVATION
Anterior compartment	Flexion of wrist Flexion of digits	Median (lateral muscles) Ulnar (medial muscles)
Posterior compartment	Extension of wrist Extension of digits	Radial nerve

Table 1.3: Muscles of the Forearm
Learn only that posterior is extension, anterior is flexion. Do not memorize specific muscle names.

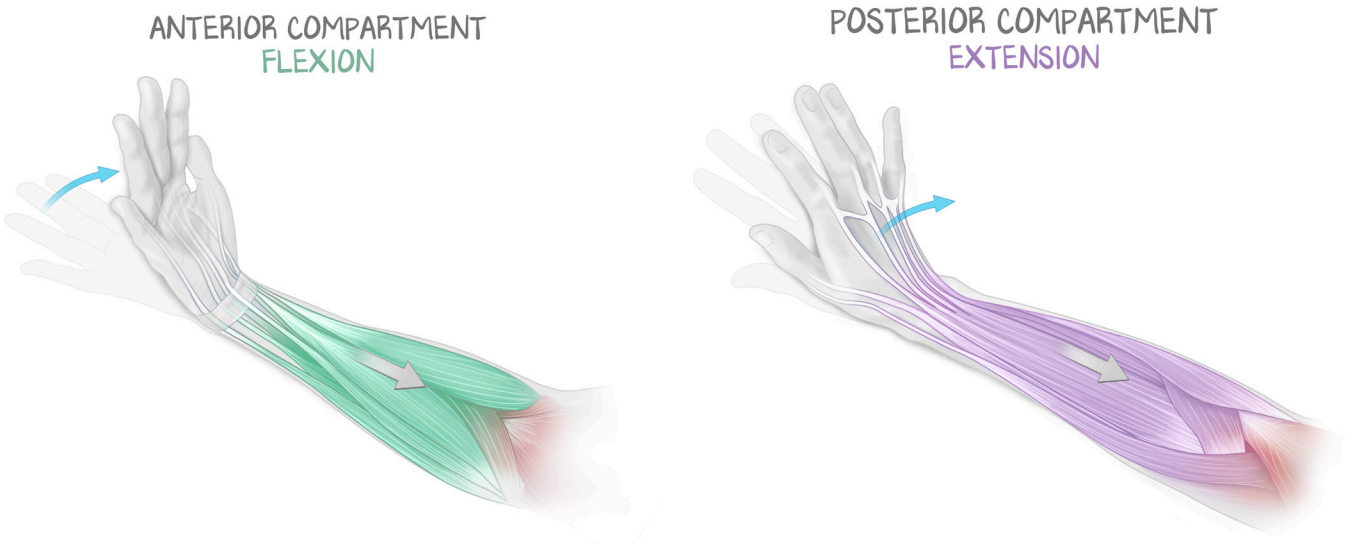

Figure 1.7: Extrinsic Muscles of the Hand
A color-coded reminder that the forearm muscles should be thought of as hand muscles, and that they can be simplified down to "anterior compartment flexion, posterior compartment extension."

The **intrinsic muscles of the hand** do require a bit of a discussion. The *extrinsic* muscles of the hand are those that come from the forearm, whose tendons pass through the wrist and attach to the digits. They are responsible for gross motor movement. The *intrinsic* muscles are responsible for fine motor movement. Nailing down the functions of the intrinsic muscles will facilitate answering questions about hand deformities based on nerve injuries—a commonly tested and commonly confused learning objective. There are thenar muscles, hypothenar muscles, lumbricals, and interossei. The **thenar muscles** (anything with "pollicis" in the name) control the movements of the **thumb** and are innervated by the **median nerve** (the median nerve is lateral, the thumb is lateral). The **hypothenar muscles** (anything with "digiti minimi" in the name) control the movements of the **pinky** and are innervated by the **ulnar nerve** (the ulnar nerve is medial, the pinky is medial). The **lumbricals** are what get students. When the lumbricals contract, they cause a **flexion at MCP** and an **extension at PIP and DIP**. This is the "shadow puppet" movement (when you make your hand talk, the thumb the bottom of the jaw), one that doesn't make a whole lot of sense in isolation. FAILURE of these muscles is what creates the unique hand deformities we get to in MSK 3: *Nerves of the Upper Extremity*. The medial lumbricals (fourth and fifth digits) are innervated by the ulnar nerve. The lateral lumbricals (first, second, and third digits) are innervated by the median nerve. The **interossei** are what let you spread your fingers (ab-duct) and tighten them against one another (ad-duct). Their function can be remembered by "DAB the PAD"—**dorsal abduct** and **palmar adduct**.

MUSCLES	ACTION	INNERVATION
Thenar muscles	Thumb motion	Median nerve
Hypothenar muscles	Pinky motion	Ulnar nerve
Lumbricals	Flex MCP, extend DIP, PIP 4th and 5th digits (medial) 1st, 2nd, 3rd digits (lateral)	Ulnar nerve Median nerve
Interossei	Dorsal Ab-duct Palmar Add-uct	Ulnar nerve

Table 1.4: Intrinsic Muscles of the Hand
Say "A. B. Duct" and "Add Uct" to distinguish movements. Right now, memorize. After lesson three, come back through here and see how much easier it is after learning the dermatomal innervations of the skin.

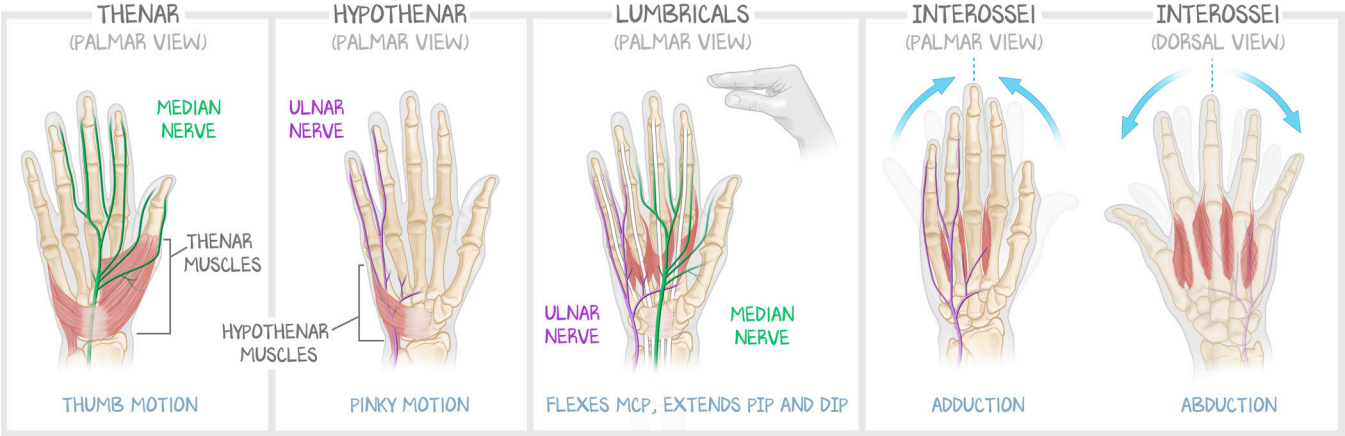

Figure 1.8: Intrinsic Muscles of the Hand
A color-coded preview of median nerve versus ulnar nerve innervation, separating the palmar hand into a lateral (first, second, third), ulnar distribution and a medial (fourth and fifth) median nerve distribution. This motor innervation of the hand muscles will also mirror the sensory innervation of the hand. The radial nerve distribution innervates the posterior muscles and skin—the posterior compartment of the forearm and the dorsal aspect of the hand.

Vasculature

On the left side of the body, the aorta gives rise to independent left carotid arteries and a left subclavian artery. On the right, a common **brachiocephalic artery** originates from the aorta and rapidly bifurcates into the right carotid artery and right subclavian artery. The **subclavian artery** is short lived and becomes the **axillary artery** in the shoulder—the name changes when it enters the shoulder region, though no bifurcation occurs.

The axillary artery has a clinically significant **anastomosis** around the **surgical neck of the humerus**, which can be injured in fracture. Then, as the axillary artery exits the deltoid into the upper arm, it is renamed the **brachial artery**, though, again, no major bifurcation occurs. The brachial artery is palpated in the arm, moving the biceps out of the way and compressing it against the humerus. The brachial artery continues until the cubital fossa, where it bifurcates into **radial** and **ulnar arteries** in the forearm, which follow their respective bones. In the hand, these arteries form anastomoses, both a **superficial palmar arch** and a **deep palmar arch**, providing significant redundancy in vascular supply to the hand.

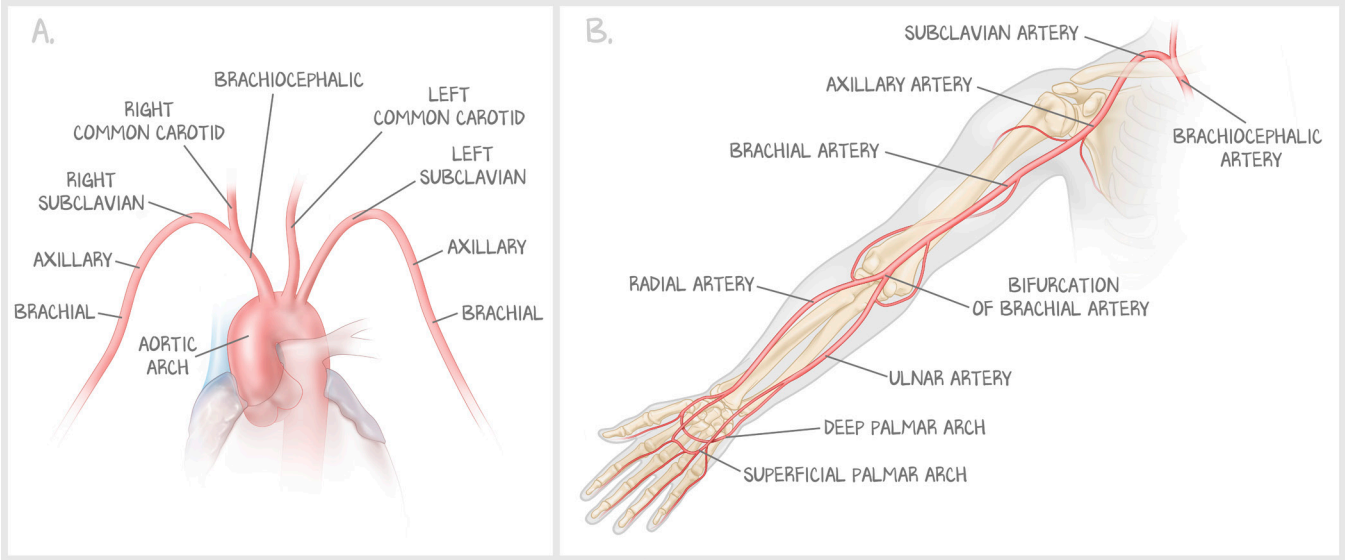

Figure 1.9: Vasculature of the Upper Extremity
(a) Three vessels branch from the aortic arch. On the right, a common artery, the brachiocephalic, bifurcates to become the subclavian and right common carotid artery. On the left, the left common carotid and left subclavian arteries branch separately from the aorta. The subclavian artery is the vascular conduit to the upper extremity. (b) The key named arteries and a visualization of their anastomosis.

Citations

Figures 1.2, 1.4: Courtesy of Jerad M. Gardner, MD.